International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 3, Jun 2018, 635-646

PERFORMANCE AND EMISSION CHARACTERISTICS OF A TWIN CYLINDER DIESEL ENGINE BLENDED BIODIESEL WITH NANO ADITIVES USING RESPONSE SURFACE METHODOLOGY

GADDALA SULOCHANA[1] & S. K. BHATTI[2]

[1]*Associate Professor, Department of Mechanical Engineering, DVR & Dr. HS MIC College of Technology, Kanchikacherla, Andhrapradesh, India*

[2] *Professor and HOD, Department of Mechanical Engineering, College of Engineering for Women, Andhra University, Visakhapatnam, Andhra Pradesh, India*

ABSTRACT

This analysis was expected to examine the consequence of injection system parameters and operating parameters (i.e injection pressure and engine load) on the performance and the ignition distinctiveness of a TC4SDIDE. Biodiesel, derived from waste fry oil and SOME through transesterification process and adjoin in nano additives such as MWCNTs blend with diesel was used as a base oil in this attempt. The testing was done on Design of Experiments based on RSM. The consequential model of the RSM was supportive to forecast the output parameters such as BSFC, BTE, CO, UHC, Soot and oxide of nitrogen and more to recognize the considerable associations among the input parameters on the outputs. The domino effect proves that the BSFC, CO, UHC, and soot was smaller, and BTE, nitrogen oxide was superior at 230 bar of injection pressure and 75% engine loads. Optimization of injection pressure was performed using the desirability approach of the RSM for superior performance and less oxide of nitrogen emission. An injection pressure of 230 bar, 100% engine loads be established to be best possible standards for the crossbreed biodiesel with nano-additives blend diesel oil operation in the trial engine operation at various loads, different pressures with constant speed.

***KEYWORDS**: Doe, Injection Pressure, MWCNTS, RSM & Operating Parameters*

Received: Apr 13, 2018; **Accepted**: May 04, 2018; **Published**: May 25, 2018; **Paper Id**.: IJMPERDJUN201868

Original Article

INTRODUCTION

At the moment the biodiesels derived starting, living thing fat, worn cookery oil etc., be second-hand as petroleum indirect injection diesel engine. Since the utilization of biodiesel as the accessible design of CI engine. Sajith*et al*[1](Sajith, Sobhan, & Peterson, 2010) carry out a testing in an SCDE by revenue of ceria nanoparticles (20–80per million) to the biodiesel of jatropha and produce a major fall within oxide of nitrogen and hydrocarbons levels, improved brake thermal efficiency. The sensible thing is that addition of ceria nanoparticles to the neat fuel acts as a barrier for oxygen, this leads to for above the ground catalytic ignition movement because of their SA-to-VR characteristics. Marquis and Chibante's(Marquis & Chibante, 2005) employment on carbon nano-tubes (CNT) represented in the improvement of SA-to-VR and settle time in the floating CNT has the support of fluid. Based on the books and writing that are published on the prospective uses and importance of CNT. SadhikBasha and Anand(Basha & Anand, 2009) cover experimental investigation of the performance and the injection characteristics of a diesel engine using CNT blended diesel. They trial extensive progress in the brake thermal efficiency and dense

damage pollutants than that of base diesel. This is unspecified because of better combustion. The previous same team (Basha & Anand, 2010) analyzed the applications of nano-particle/nano-fluid in diesel engine and accomplished that the addition of up fit fraction of CNT/nanoparticles to the known fuels like diesel helps in decreasing the time for the evaporation, and also favors in shorter ignition delay. due to the possible properties of CNT/nano-particles. The present ongoing work is targeted at establishing the effects on the combustion characteristic, performance, and emission of a uni-cylinder direct injection diesel engine by using MWCNTs blended diesel fuel. (Abd Alla, Soliman, Badr, & Abd Rabbo, 2002; Agarwal, 2007; Azam, Waris, & Nahar, 2005; Devan & Mahalakshmi, 2009; Lapuerta, Armas, & Rodríguez-Fernández, 2008; Rao, Sampath, & Rajagopal, 2008; Subramanian, Singal, Saxena, & Singhal, 2005). Amongst the different constraint of curiosity, which enclose the feasible of persuading the recital and nitrogen oxide giving out, the injection pressure and amendment of this parameter considered to be an excellent system of in-cylinder ignition development. The unique sound property of addition system parameters is broadly revised for biodiesel fuelled compression ignition engine. It is observed by the research scholar's review (Bakar RA, 2008; Bari S, Yu CW, 2003; Benajes J, Molina S, Garcia JM, 2004; Buyukkaya & Cerit, 2008; İçıngür & Altiparmak, 2003; Kong, 2016; Lyu & Shin, 2002; Ma, Huang, Li, Wang, & Miao, 2007; Mani & Nagarajan, 2009; Nwafor, Rice, & Ogbonna, 2000; Pandian, Sivapirakasam, & Udayakumar, 2009; Puhan, Jegan, Balasubbramanian, & Nagarajan, 2009; Rente T, Gjirja S, 2004; Roy, 2013; Sayin & Canakci, 2009; Sayin, Uslu, & Canakci, 2008; Venkanna, Wadawadagi, & Reddy, n.d.) the grate decrease in nitrogen oxide hazards, similarly, enhancement of the engine performance, characteristics of combustion and injection parameters playa dominant role in CI engine. Prior reading explains the consequence of injection system parameters had been exploring by changing parameters at a single time. But the combustion process in CI Engines is extremely inclined by the fused outcome of different parameters and operating parameters. From now, a regular multivariate reading can single offer a obvious moreover systematic considerate taking place the burning sameness of the engine than the come up to by means of only one parameter at a time study. Non linear problems are used to solve the multivariate problems such as Design of Experiments (DoE), fuzzy logic and neural network out of three DoE has the most potent with economical technique to access the individual and mixed effects of input factors on output reply. Even if the minority studies were replied by using DoE for the application of internal combustion engines, the research on combined effects that are in between injection system parameters like injection timing, injection pressure and nozzle tip protrusion on the (Reddy & Ramesh, 2016) are used Taguchi approach to find the optimization of performance of alternate fuel (jatropha) diesel engine model. Anand and Karthikeyan(Anand G, n.d.)are used Taguchi method for SI engine to optimize the parameters of the engine with gaseous fuels. Lee and Reitz (Lee & Reitz, 2016) optimize a high speedDIDE with common rail injection system using Response surface methodology Win et al. (Win, Gakkhar, Jain, & Bhattacharya, 2015) optimize the load, static injection timing, and speed of a CI engine with diesel to reduce fuel consumption, noise and exhaust emissions by using Response surface methodology, and Satake et al. (Industries, 2014) performs diesel engines development based on the fuel injection control using RSM based optimization technique.

The Present work is to learn the entity and united special consequence of injection system parameter on the recital and production of the DE characteristics, employ diesel–biodiesel blend as oil utilize RSM base trial plan plus the additional purpose is to find out the most favorable values of injection pressure and operating variables would be answering result in better presentation with insignificant emission of oxide of nitrogen by leaving consequence of oxide of carbon and hydrocarbon emissions using the required approach of statistical optimization.

MATERIALS AND THEIR METHODS

Preparation of Hybrid-Biodiesel

Biodiesel, it was made of the waste of frying oil in the Laboratory of Mechanical Engineering department in the QIS College Of Engineering And Technology. The feedstock was collected from potato chips industry at Vijayawada. For manufacturing biodiesel from the used vegetable oil, we have to carry out a small-scale transesterification reply in the laboratory circumstances. The entry of catalyst amount, the temperature required for the reaction and time had to be resolute. Later, large-scale methods were applied by using beaker (reactor tank). Now25grms methanol and one Liter waste fry oil with 12 to 15-gram potassium hydroxide (KOH) as a catalyst. After preparing the solution of methanol at 70^{o}c temperature with added catalyst, the moisture, frying oil was supplementary to the reaction tank for transesterification reaction. The mixture was agitated for 5 hours at 65^{o}c-70^{o}c. After the partition of glycerol, warm water was used for washing the obtained biodiesel. The washing process was done for 5 to 10 times, later, ester disclosed for the free heating process at a nearly100^{o}c temperature in the presence of atmospheric conditions. The final sketch alcohol and humidity are removed from biodiesel. The same procedure was carried out in preparation of Sesame oil methyl ester (SOME) and diesel was purchased from a saleable supplier.

The measured properties of ester fuels as shown in Table1. Tested methyl ester was pure and its blended with 20% (v/v) ratio of neat diesel fuel (NDF) with anno additives. The properties of the test fuels are shown in Table 2 as following. Tested fuels were coded as following: neat diesel fuel (NDF), methyl ester hybrid biodiesel With nano additives (MEHBWNA), 5%WFOME + 5%SOME+25ppm + 90%NDF (B10+25ppm), 10%WFOME + 10%SOME+25ppm + 80%NDF(B20+25ppm), 5%WFOME + 5%SOME + 50ppm + 90%NDF(B10+50ppm), and 10%WFOME + 10%SOME + 25ppm-80%NDF(B20+50ppm).

Table 1: Properties of Nanotubes

S.No	Parameters	MWCNT Type -16
1	Manufacturer	SISCO Research Laboratories Pvt-Ltd
2	Purity($_{\%}$)	96
3	Surface Area(SSA), m^2/g	351
4	Average Particle Size(APS)mm	10-30mm Length; diameter=0.5-2mm
5	Thermal Conductivity, W/m ^{0}K	3182
6	True Density, g/cc	0.05-0.178

Table2: MWCNTs Blended Fuel Properties

S. No	Types of Fuels	Density @15^{0}C kg/m	Net Calorific Value Mj/kg	Flash Point ^{0}C	Fire Point ^{0}C	Kinematic Properties cst @40^{0}C
1	Diesel	832	44.8	53	58	3.22
2	Waste Fry Oil	856	39.85	160	162	3.98
3	WFOME	848	43.85	160	164	4.21
4	B2+25ppmMWCNTs	830	43.73	57	61	4.75
5	B2+50ppmMWCNTs	831.1	43.93	65	81	4.45
6	Sesame Oil	861	37.03	255	261	3.25
7	SOME	839	44.164	58	63	4.7335

Equipment and Materials

The current work is carried out with the experimental set-up available at ATALON Company, Chennai. A Tractor engine (Sympson's make) is used having a dual-cylinder, direct-injection vertical in-line diesel engine coupled with eddy

current dynamometer for loading. An AVL gas analyzer Di Gas 444, an AVL 437 smoke meter are used to analyze exhaust gases. A combustion analyzer (Model ECA1.0.1) is used which capable of recording data from all the sensors at different load conditions. Simpson's piezoelectric pressure transducer and a crank-angle encoder are as shown in Fig.3. In table 3 the details of engine specifications are given. The five-gas analyzer and smoke meter are utilized to examine the soot and five emissions (NO_x, CO, CO_2 UHC and O_2). The temperature of the outlet discharge gases is measured with k-type chrome–alumel thermocouple. The piezoelectric pressure transducer is arranged on the head of the cylinder and the crank angle encoder was fixed to the engine output shaft. It was used to analyze the characteristics of combustion of compression ignition engine. The rate of heat release and ignition delay was expected by averaged the cylinder pressure data of fifty successive cycles using a computer program. The tests were conducted with the neat diesel and allowing the engine to warm up and then changing to either the hybrid biodiesel with nano-additives (HBWNA)–diesel fuel. At the end of the test, the engine was operated with the neat diesel to HBA – diesel from the fuel line system. All the experiments were conducted at a constant speed of 1500 rpm by changing the loads (0%-100%) and injection pressure(220bar to 240 bar) using the neat diesel, blended HBWNA fuels at a constant injection timing of 24.5 ^{o}C TDC.

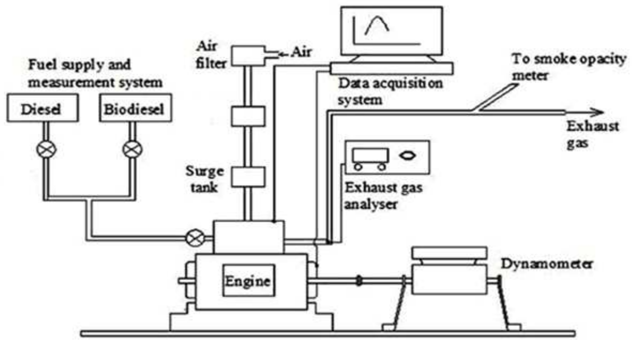

Figure 1: Schematic Layout of the Experimental Setup

Response Surface Methodology (RSM)

By using RSM current study the engine modeling and for examining of reaction parameters to categorize the distinctiveness of the engine. Following step ladder is regarding the plan and investigation

Step 1: To choose the parameters so as to impact the recital and discharge distinctiveness. In this research, injection pressure and operating parameters were measured as the parameters of inputs.

Step 2: The pressure of injection systems (represented 'p_i')was changed at 5 levels as a step of 5bar which range 220 bar to 240 bar and load(indicated by 'l_e') change from 0% to 100%. The key parameters were taken based on the limits of permissible.

Step 3: Assessment of the engine performance is done by DoE. The engine performance is larger than the full range of difference of injection system variables of fewer experiment numbers. The matrix of the design was chosen based taking place the fractional factorial plan of RSM generates final the software ''Design expert'' version 10.0.1 of Stat ease, which contains 13 trial runs shown in Table 3.

Step 4: The experiment that is conducted on the engine, as per order had their responses on the response line.

Step 5: The multiple decay examination was agreed to find out the coefficients, equations can be used to forecast the responses. Statistically, the momentous model has used the alliance among the process parameters and the quite a lot of responses were obtained.

Step 6: As a final point, the most favorable values of the injection pressure and engine load were obtained by using the desirability approach of the RSM.

Table 3: Engine Specifications

S. No	Parameter	Engine
1	Type /configuration	Vertical in-line diesel engine
2	Bore x Stroke	91.44mm,127mm
3	No. of cylinders	2
4	Displacement	1670 cc
5	Compression ratio	18.5:1
6	Cycle	4stroke
7	Rotation	Clockwise(viewed from front)
8	Aspiration	Natural
9	Combustion system	Direct injection
10	Fuel pump	MICO Bosch In-line pump
11	Engine starting system	Electrical
12	Cooling System	Water
13	Electrical system	12 Volts (Dynamo /Alternator)
14	Flywheel housing	SAE 1 or SAE 3
15	Flywheel	can be made to suit the application
16	Weight(Bare Engine)	200kg
17	Length x width x height	489 x 536 x 756 mm
18	Fan center from the crankcenter	282.6mm
19	Power Takeoff	From crankshaft axially or radially, gear driven PTO training gears on LHS beneath fuel pump
20	Air –compressor	Optional

Table 4: Experimental Design Matrix

S. No	Std	Run	Pressure (bar)	Load (%)	Brake Thermal Efficiency (%)	BSFC (kJ/kW h)	CO (vol %)	UHC (ppm)	NOx (ppm)	Soot Opacity (%)
1	8	01	230	100	35.01	0.3156	0.47	44	271	86.6
2	12	02	230	50	30.88	0.2084	0.40	38	275	34.6
3	7	03	230	0	0	0	0.32	34	625	4.6
4	4	04	240	100	34.21	0.325	0.57	55	745	86
5	5	06	220	50	29.82	0.12217	0.46	47	565	32.5
6	9	07	230	50	30.88	0.2084	0.40	38	649	34.6
7	2	08	240	0	0	0	0.48	50	280	5
8	13	09	230	50	30.88	0.2084	0.4	38	649	34.6
9	6	10	240	50	27	0.212	0.49	52	700	29.7
10	11	11	230	50	30.88	0.2084	0.40	38	649	34.6
11	1	12	220	0	0	0	0.33	39	371	3.6
12	10	13	230	50	30.88	0.2084	0.40	38	649	34.6

Desirability Approach

The function of desirability approach was extensively utilized in industries for optimization of several response processes. It depends on whether a fastidious outputs $Z_j$is to be maximized, minimized, or assigned a target value, different function of desirability $D_j(Z_j)$ can be used,(D_j) and it ranges between di = 0, which suggested in response be completely unacceptable, and D_j=1, which suggests that the response is more enviable. In the current toil, RSM based desirability approach is worn for the Z property of responses (brake specific fuel consumption, BTE, an oxide of carbon, hydrocarbons, soot, and oxide of nitrogen. The optimization investigation is passed out using DoE software, where each response is changed to a dimensionless desirability value. The desirability of each response can be calculated by the following equations with respect to the goal of each response in favor of ambition of minimum,

D_j=1 when $Z_j \leq$ low;D_j=0 when $Z_j \geq$ high; and

$D_j=(high_j-Z_j/high_j-low_j)^{wtj}$ When $low_j \leq Z_j \leq high_i$

To achieve maximum, D_j=0 when $Z_j \leq$lowj; D_j=1 when $Z_j \geq$ high; and

$D_j=(Z_j–low_j /high_j-low_j)^{wtj}$ When $low_j \leq Z_j \leq high_j$

as target, D_j=0 when $Z_j<low_j$; Z_j>highj

$D_j=(Z_j-low_j /T_j-low_j)^{wtj}$ when $low_j<Z_j<T_j$

$D_j=(Z_j–high_j /T_j-high_j)^{wtj}$ when $T_j<Z_j<high_j$; and

Inside the range, D_j=1 when $low_j<Z_j$<highandD_j=0; otherwise, Where “j” represents the response, “Z” is the value of the response. Response lower limit is denoted by “low”, and upper limit denoted as “high”, “ T” is the response target value and “wt” denotes the response weight, the form of the popularity purpose can be altered by the weight field for every response. To provide further prominence to the lower/ upper limits weights are used. The range of weights is from 0.1 to 10; wt >1 gives extra highlighting to the goal, wt< 1 give a smaller amount importance. When wt = 1, the desirability function varies linearly. The desirability approach which is used to solve multiple response optimizations involves a technique of the overall desirability function, B(0≤B≤1) which is a combination of many responses into a dimensionless measure of performance and is planned by $B=(\pi^{n}{}_{j=1} D_j^{Tj})1/Ɛrj$.

In overall desirability objective function (B), every reply is able to assign significance (r), family member to the additional outputs. Magnitude varies from the slightest imperative value of 1, denoted by (+), the mainly essential value of 5, denoted by^{d}d0 (+++++). A high value of B indicates the more desirable and best functions of the system which is considered as the optimal solution. The optimum values of factors are determined from the value of individual desired functions (D) that maximizes B.

RESULTS AND DISCUSSIONS

Analysis of the Model

The investigation was based on the analysis of variance (ANOVA) which provides numerical information of m value. The parameters of ANOVA such as brake specific fuel consumption, brake thermal efficiency, carbon oxide, hydrocarbons, smoke opacity and NO_x emissions are given in Table 5. The models to be significant as “m” values are.

Table 5: ANOVA for Various Response Surface Quadratic Models Denoted by ‘m’ Values

S. No	SOURCE	BTE	BSFC	CO	UHC	NO_X	SOOT
1	model	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
2	Pi	0.6690	0.1165	0.0004	<0.0001	<0.0001	0.7748
3	Le	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
4	Pi*le	0.1452	0.5424	0.0014	0.0006	0.0001	0.7265
5	Pi^2	0.0380	0.0068	<0.0001	<0.0001	0.0986	0.0262
6	le^2	<0.0001	<0.0001	0.5989	0.5207	<0.0001	<0.0001

* The insignificance of the input parameter over the output responses on “m” value greater than 0.05.

In case less than 0.05, the quadratic models for the responses were developed in terms of actual factors.

Given below as Eqs.(1)–(6).

Final Equation in Terms of Coded Factors

$$BTE= +30.74+0.24*Pi+16.53*le+1.06*Pile-1.98*Pi^2-12.89*le^2 \quad (1)$$

$$BSFC=+0.21-2.283E-003*Pi+0.16-1.000E-003*Pixle+7.122E-003*Pi^2-0.052*B^2 \quad (2)$$

$$CO= +0.40+0.033*Pi+0.077*le-0.033*Pixle+0.081*Pi^2+1.034E-003*le^2 \quad (3)$$

$$UHC=+38.21+3.17*Pi+4.67*le-2.00*Pixle+10.78*Pi^2+0.28*le^2 \quad (4)$$

$$NOx= 647.79+52.67*Pi+194.50*le+40.75*Pixle-12.28*Pi^2-169.78le^2 \quad (5)$$

$$Smoke\ Opacity= +34.20-0.15*Pi+40.82*le-0.22*Pixle-2.09*Pi^2+12.41*le^2 \quad (6)$$

Evaluation of the Model

Analysis of variance (ANAVO) was used to validate the model's stability for different responses as shown in table 4. It is observed from the output, with’ m value less than 0.0001 the model was significant. 0.05 was chosen as reference limit for ‘m’ values. The regression statistics goodness of fit (R^2) and the goodness of prediction (Adjusted R^2) shown in Table5 for all responses. The total changeability report was indicated by the R^2 value by considering the significant factors. In the model, the number of predictors was given by the adjusted R^2 values. Both the values indicate that the model fits the data very well (Win et al., 2015).

Table 6: Response Surface form Appraisal

S. No	MODEL	BTE	BSFC	CO	UHC	NO_X	SOOT
1	Mean	23.88	0.00312	0.44	43.31	563.77	38.96
2	Std. Deviation	1.29	0.19	0.013	0.68	10.71	1.24
3	Model Degree	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
4	R^2	0.9949	0.996	0.9836	0.9946	0.9977	0.9990
5	Adj.R^2	0.9912	0.9993	0.9719	0.9907	0.9961	0.9982
6	Pred.R^2	0.9487	0.9959	0.8387	0.9535	0.9771	0.9915

Interactive Product of Injection Pressure and Engine Load

The interactive cause of engine load and injection pressure on BTE, BSFC, CO, UHC, NO_x and Smoke Opacity are shown in Figures 2–7respectively.

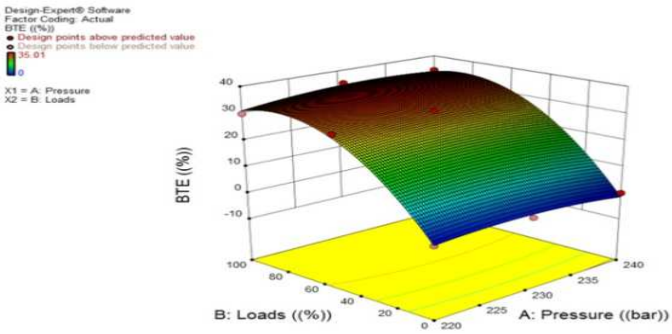

Figure 2: BTE Verses Engine Loads and Injection Pressure

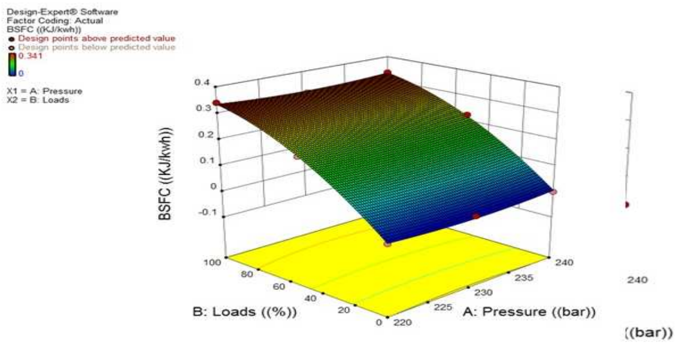

Figure 3: BSFC Verses Engine Loads and Injection Pressure

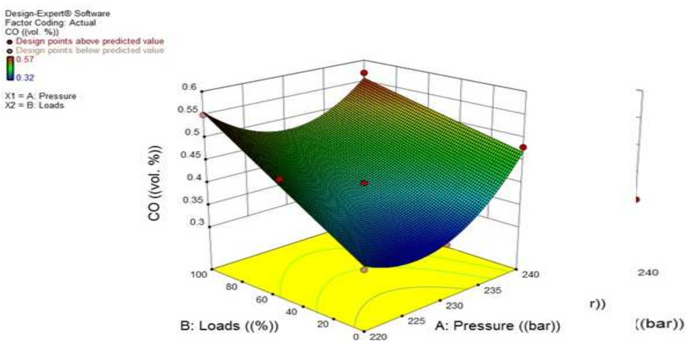

Figure 4: CO Versus Engine Loads and Injection Pressure

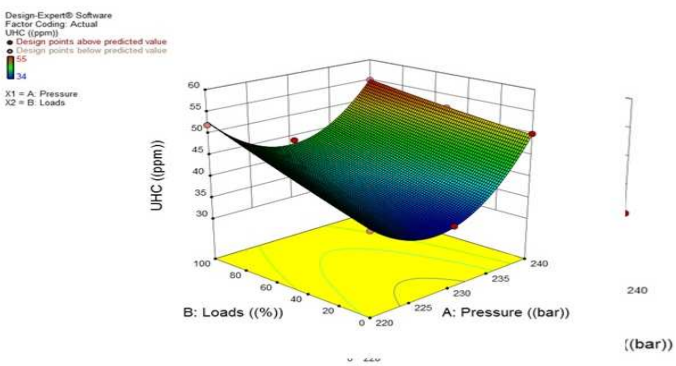

Figure 5: UHC Verses Engine Loads and Injection Pressure

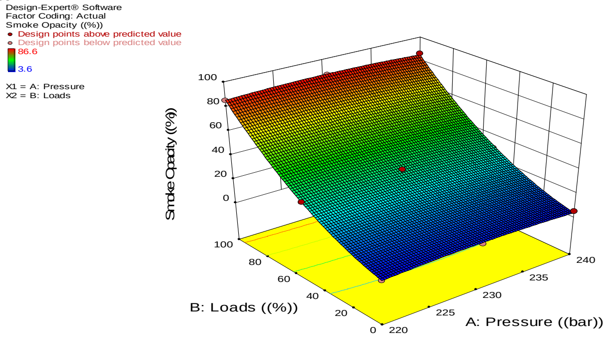

Figure 6: Soot Verse Engine Loads and Injection Pressure

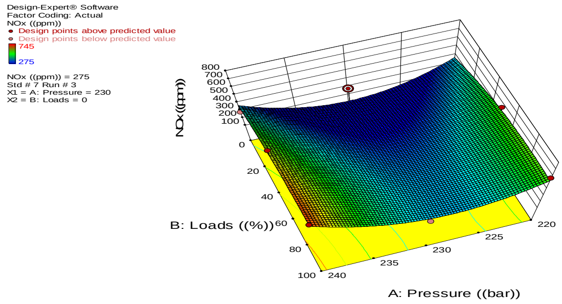

Figure 7: NOx Verse Engine Loads and Injection Pressure

Optimization

The performance, hazards characteristics discovered at the lowest injection pressure and increased engine load. The results indicated that Values of BTE and oxide of nitrogen are very low and brake specific fuel consumption, carbon monoxide, hydrocarbons, Soot values are high. The higher BTE and oxide of nitrogen with lower brake specific fuel consumption, carbon monoxide, hydrocarbons and soot values were predicted at an injection pressure of 240 bar with 100% of engine load. To compromise between Brake Thermal efficiency and oxide of Nitrogen and other emissions, it needs to optimize the injection pressure and engine load to minimizing the oxide of Nitrogen and enhancing the brake thermal efficiency but no such compromise takes place on the brake specific fuel consumption and other emissions. The criteria for the optimization such as a goal set for each response, lower and upper limits used, weights used and factors are presented in Table 6. In desirability based approach, where dissimilar best solutions are obtained. The solution with high desirability is preferred and the maximum desirability of 0.99 was obtained following with the injection pressure and engine load. That could be measured as the optimum parameters for the test engine.

Table 7: Optimization of Criteria and Desirability of Response

S.No	Parameters or Response	Limits		Weights		Importance	Criteria	Desirability
1	Pressure of Injection (bar)	220	240	1	1	3	In range	01
2	Operating Parameters (%)	0	100	1	1	3	In range	01
3	BTE(%)	0	35.01	1	1	3	Maximize	0.979
4	BSFC(Kj/kw h)	0	0.329	1	1	3	Maximize	0.985
5	UHC(ppm)	34	55	1	1	5	Maximize	0.974
6	CO(Vol,%)	0.32	0.57	1	1	5	Maximize	0.964
7	NOx(ppm)	271	745	1	1	5	Minimize	0.972
8	Soot (%)	3.6	86.6	1	1	5	Minimize	0.982

Validation of the Optimized Results

The experiments are conducted at the optimum pressure in injection system and the engine load to classify the optimized results. The average of six actual response was calculated. The actual values, predicted values and error percentages are tabulated in table 7. The predicted values show the developed model was absolutely accurate as the error percentages in the calculation were in a fine agreement.

Table 8: Validation Test Results

Exp No	Injection Pressure (bar)	Engine Load (%)		BTE (%)	BSFC (kJ/kWh)	UHC (ppm)	CO (Vol. %)	NOx (ppm)	Soot
01	240	65.579	Actual	35.01	0.329	55	0.57	275	86.6
			Predicted	33.224	0.259	53	0.52	271	85.1
			%Error	0.051	0.212	3.63	0.08	1.45	1.73

CONCLUSIONS

Here the succeeding conclusions on the stage the number of tests in a twin cylinder diesel engine with changeable the injection pressure and engine load:

- The Design of Experiments is greatly supportive of the devise test and the numerical study help to categorize the considerable parameters which mainly influence the performance and emission characteristics. The test plan significantly compacts the moment compulsory to reducing the number of experiments that are performed and provided statistically verified and used for all outputs.
- Advancing engine loads from 0% to 100% help to shrink the carbon-monoxide, hydrocarbons and soot emissions with Oxide of nitrogen emissions increases.
- Growing injection pressure, which is contributed for superior brake thermal efficiency with slight brake specific fuel consumption by lesser carbon-monoxide, hydrocarbons and soot emissions and $NO_{x,}$ at all engine, loads Conversely when the injection pressure is too high the results are considerable.
- The response surface methodology of Desirability approach was established for simplest and capable optimization technique. As 0.905 superior desirability was obtained at optimum injection system parameters i.e.230bar of injection pressure, engine load at 100%, are the values of the brake specific fuel consumptions, brake thermal efficiency, carbon-monoxide, hydrocarbons, smoke opacity, and soot was found to be 0.259kJ/kW h, 33.224%, 52.7%, 53ppm, 45.811% and 271 ppm correspondingly.

REFERENCES

1. *Abd Alla, G.., Soliman, H.., Badr, O.., & Abd Rabbo, M.. (2002). Effect of injection timing on the performance of a dual fuel engine. Energy Conversion and Management, 43(2), 269–277. https://doi.org/10.1016/S0196-8904(00)00168-0*
2. *Agarwal, A. K. (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science, 33(3), 233–271. https://doi.org/10.1016/j.pecs.2006.08.003*
3. *Anand G, K. B. (n.d.). An investigation and engine parameters optimization of a spark ignition engine with gaseous fuels. In 4th Dessau gas engine conference, WTZ RoBlau gGmbH, Germany.*

4. Azam, M. M., Waris, A., & Nahar, N. M. (2005). Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. Biomass and Bioenergy, 29(4), 293–302. https://doi.org/10.1016/j.biombioe.2005.05.001
5. Bakar RA, S. I. (2008). Fuel injection pressure effect on performance of direct injection diesel engines based on experiment. Am J Appl Sci, 5(3), 197–202.
6. Bari S, Yu CW, L. T. (2003). Effect of fuel injection timing with waste cooking oil as a fuel in a direction injection diesel engine.
7. Basha, J. S., & Anand, R. (2009). Performance and emission characteristics of a DI compression ignition engine using carbon nanotubes blended diesel. Proceedings of the International Conference On. Retrieved from https://scholar.google.com/scholar?q=Performance+and+emission+characteristics+of+a+DI+compression+ignition+engine+using+carbon+nanotubes+blended+diesel
8. Basha, J. S., & Anand, R. (2010). Applications of nanoparticle/nanofluid in compression ignition engines–a case study. Int. J. Appl.Eng.Res.Retrievedfromhttps://scholar.google.com/scholar?q=Applications+of+nanoparticle+%252Fnanofluid+in+compression+ignition+engines+%25E2%2580%2593+a+case+study
9. Benajes J, Molina S, Garcia JM, N. R. (2004). nfluence of boost pressure and injection pressure on combustion process and exhaust emissions in a HD diesel engine. SAE International 2004-01-1842, 834–45.
10. Buyukkaya, E., & Cerit, M. (2008). Experimental study of NO x emissions and injection timing of a low heat rejection diesel engine, 47(x), 1096–1106. https://doi.org/10.1016/j.ijthermalsci.2007.07.009
11. Devan, P. K., & Mahalakshmi, N. V. (2009). A study of the performance, emission and combustion characteristics of a compression ignition engine using methyl ester of paradise oil-eucalyptus oil blends. Applied Energy, 86(5), 675–680. https://doi.org/10.1016/j.apenergy.2008.07.008
12. İçıngür, Y., & Altiparmak, D. (2003). Effect of fuel cetane number and injection pressure on a DI Diesel engine performance and emissions. Energy Conversion and Management, 44(3), 389–397. https://doi.org/10.1016/S0196-8904(02)00063-8
13. Industries, M. H. (2014). The Rapid Development of Diesel Engines Using an Optimization of the Fuel Injection Control, 6–10.
14. Kong, S. (2016). Experimental Study on Effects of Nozzle Hole Geometry on Achieving Low Diesel Engine Emissions, 132(February 2010), 1–10. https://doi.org/10.1115/1.3124791
15. KB, Sai Sanjana. "Thermal Analysis of Advanced IC Engine Cylinder." (2016).
16. Lapuerta, M., Armas, O., & Rodríguez-Fernández, J. (2008). Effect of biodiesel fuels on diesel engine emissions. Progress in Energy and Combustion Science, 34(2), 198–223. https://doi.org/10.1016/j.pecs.2007.07.001
17. Lee, T., & Reitz, R. D. (2016). Optimization of a High-Speed Direct-Injection Diesel Engine Equipped With a Common Rail, 125(April 2003), 541–546. https://doi.org/10.1115/1.1559900
18. Lyu, M., & Shin, B. (2002). Study of nozzle characteristics on the performance of a small-bore high-speed direct injection diesel, 3(2), 69–79.
19. Ma, Z., Huang, Z., Li, C., Wang, X., & Miao, H. (2007). Effects of Fuel Injection Timing on Combustion and Emission Characteristics of a Diesel Engine Fueled with Diesel - Propane Blends, 21(8), 1504–1510.

20. *Mani, M., & Nagarajan, G. (2009). Influence of injection timing on performance, emission and combustion characteristics of a DI diesel engine running on waste plastic oil. Energy, 34(10), 1617–1623. https://doi.org/10.1016/j.energy.2009.07.010*
21. *Marquis, F. D. S., & Chibante, L. P. F. (2005). Improving the Heat Transfer of Nsnofluids and Namolubricants with C ? bon Nsnot "._ --, d(December).*
22. *Nwafor, O. M. I., Rice, G., & Ogbonna, A. I. (2000). E ect of advanced injection timing on the performance of rapeseed oil in diesel engines, 21, 433–444.*
23. *Pandian, M., Sivapirakasam, S. P., & Udayakumar, M. (2009). Influence of Injection Timing on Performance and Emission Characteristics of Naturally Aspirated Twin Cylinder CIDI Engine Using Bio-diesel Blend as Fuel, 1(5), 113–117.*
24. *Puhan, S., Jegan, R., Balasubbramanian, K., & Nagarajan, G. (2009). Effect of injection pressure on performance, emission and combustion characteristics of high linolenic linseed oil methyl ester in a DI diesel engine. Renewable Energy, 34(5), 1227–1233. https://doi.org/10.1016/j.renene.2008.10.001*
25. *Umesh, KS, VK Pravin, and K. Rajagopal. "Experimental Investigation and CFD Analysis of a Multi-Cylinder four stroke SI Engine Exhaust Manifold for Optimal Geometry to Reduce Backpressure and to Improve Fuel Efficiency."*
26. *Rao, G. L. N., Sampath, S., & Rajagopal, K. (2008). Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with Used Cooking Oil Methyl Ester and its Diesel Blends, 2(1), 90–96.*
27. *Reddy, J. N., & Ramesh, A. Ã. (2016). Parametric studies for improving the performance of a Jatropha oil-fuelled compression ignition engine, 31(2006), 1994–2016. https://doi.org/10.1016/j.renene.2005.10.006*
28. *Rente T, Gjirja S, D. I. (2004). Experimental investigation of the effect of needle opening pressure (NOP) on combustion and emissions formation in a heavy duty DI diesel engine. SAE International 2004-01-2921, 1692–1711.*
29. *Roy, M. M. (2013). Effect of Fuel Injection Timing and Injection Pressure on Combustion and Odorous Emissions in DI Diesel Engines, 131(September 2009), 1–8. https://doi.org/10.1115/1.3185346*
30. *Sajith, V., Sobhan, C. B., & Peterson, G. P. (2010). Experimental investigations on the effects of cerium oxide nanoparticle fuel additives on biodiesel. Advances in Mechanical Engineering, 2010(March). https://doi.org/10.1155/2010/581407*
31. *Sayin, C., & Canakci, M. (2009). Effects of injection timing on the engine performance and exhaust emissions of a dual-fuel diesel engine. Energy Conversion and Management, 50(1), 203–213. https://doi.org/10.1016/j.enconman.2008.06.007*
32. *Sayin, C., Uslu, K., & Canakci, M. (2008). Influence of injection timing on the exhaust emissions of a dual-fuel CI engine, 33, 1314–1323. https://doi.org/10.1016/j.renene.2007.07.007*
33. *Subramanian, K. A., Singal, S. K., Saxena, M., & Singhal, S. (2005). Utilization of liquid biofuels in automotive diesel engines: An Indian perspective. Biomass and Bioenergy, 29(1), 65–72. https://doi.org/10.1016/j.biombioe.2005.02.001*
34. *Venkanna, B. K., Wadawadagi, S. B., & Reddy, C. V. (n.d.). Effect of Injection Pressure on Performance, Emission and Combustion Characteristics of Direct Injection Diesel Engine Running on Blends of Pongamia Pinnata Linn Oil (Honge oil) and Diesel Fuel, XI(1316), 1–17.*
35. *Win, Z., Gakkhar, R. P., Jain, S. C., & Bhattacharya, M. (2015). Parameter optimization of a diesel engine to reduce noise, fuel consumption, and exhaust emissions using response surface methodology, 219, 1181–1192. https://doi.org/10.1243/095440705X34919*